PHOTOCHEMICAL EVOLUTION OF CONDENSED ORGANICS IN TITAN'S LOWER ATMOSPHERE AND ON THE SURFACE. Murthy S. Gudipati[1], Isabelle Couturier-Tamburelli[2], Benjamin Fleury[3], Nathalie Carrasco[3], Antti Lignell[4], Ronen Jacovi[5]. [1]Science Division, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA, gudipati@jpl.nasa.gov; [2]Aix-Marseille Université, laboratoire Physique des interactions ioniques et moléculaires, 13397 Marseille cedex 20 France; [3]Laboratoire Atmospheres, Milieux, Observations Spatiales (LATMOS), Université de Versailles Saint-Quentin-en-Yvelines, France; [4]Present Address: Arthur Amos Noyes Laboratory of Chemical Physics, California Institute of Technology, Pasadena, CA 91125, USA; [5]Present Address: KLA-Tencor, Algo-OMD-PSG, Ha'Lavyan 1st St., Migdal Ha'Emek, Israel, 23100.

Introduction: Fractionation of planetary systems is both interesting and puzzling. While the Jovian satellite Io seems to be enriched with sulfur and Europa and Ganymede with ice, Titan - the largest moon of Saturn is enriched with organics, and it is the third body in our solar system known to have significant atmosphere after Earth and Venus. Thus, Titan has at least two confirmed key ingradients for life as we know (energy and organics). Models suggest that Titan's interior is composed of fractionated rocks, minerals, and ice (water), making Titan's interior potentially habitable.

Titan's Atmosphere and Surface: Chemistry on Titan is known to be driven by ultraviolet photons and solar wind in its upper atmosphere [Teanby, Irwin et al. 2012] and essentially no chemical activity in its lower atmosphere or on the surface, except for cosmic ray penetration to the surface [Zhou, Zheng et al. 2010] and tidal forces in the interior [Sohl, Hussmann et al. 2003; Tobie, Mocquet et al. 2005]. However, Titan's lower atmosphere receives photons [Karkoschka, Schroder et al. 2012] with a spectral distribution somewhat similar to Earth's (maximizing at ~500 nm) but several orders of magnitude lower flux. Hence, photochemical processes similar to that occur on Earth's surface could occur in Titan's lower atmosphere and surface [Lunine and Horst 2011] as well – only taking several orders of magnitude longer to compensate the flux differences. Titan's surface receives a significant portion of these longer wavelength photons, making longer-wavelength photons driven photochemistry an important - should it be viable - process in the chemical evolution of Titan. While majority of Titan's atmosphere is composed of molecular nitrogen, methane dominates the minor components and the rest are H,C,N-containing species and are oxygen depleted. Hence, formation of nitriles and polyyenes are expected, observed, and recently been shown to be potential alternatives for lipid bilayers depleted of oxygen [Stevenson, Lunine et al. 2015]. Titan's haze region in the lower atmosphere and surface are dominated by condensed organics - making condensed-phase photochemistry important process on Titan.

Laboratory Studies Simulating Titan's Atmosphere and Surface: Photochemical processes in the gas phase and in the condensed phase are significantly different due to intermolecular interactions. For this reason, we have been conducting systematic laboratory studies on condensed ices of Titan's atmospheric molecular ices as well as laboratory analogs (also known as tholins) of high-energy processed aerosols simulating the haze particles. We have shown that indeed such photochemistry could occur in Titan's atmosphere by comparing the condensed-phase properties of Titan's organic molecules with the available solar photons at lower altitudes [Couturier-Tamburelli, Gudipati et al. 2014; Gudipati, Jacovi et al. 2013]. Most of the biomolecules on Earth are tuned to absorb at the maximum of solar flux (400 – 700 nm) and such molecules could be made on Titan in its atmosphere and rain down to the surface. We will discuss the scenarios of synthesis of complex biologically relevant molecules on Titan's surface and in the atmosphere focusing on the available solar photons in these environments.

Acknowledgments: This research was enabled through partial funding from JPL's DRDF and R&TD programs for infrastructure of the "Titan Organic Aerosol Spectroscopy and chemisTry (TOAST) Laboratory" at JPL; and funded by NASA Planetary Atmospheres, Cassini Data Analysis Programs, and past NAI "Titan as a Prebiotic Chemical System". This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

References:

Couturier-Tamburelli, I., Gudipati, M. S., et al. (2014). Icarus **234**: 81-90.

Gudipati, M. S., Jacovi, R., et al. (2013). Nature Communications **4**: 1648.

Karkoschka, E., Schroder, S. E., et al. (2012). Planetary and Space Science **60**(1): 342-355.

Lunine, J. I. and Horst, S. M. (2011). Rendiconti Lincei-Scienze Fisiche E Naturali **22**(3): 183-189.

Sohl, F., Hussmann, H., et al. (2003). Journal of Geophysical Research-Planets **108**(E12): 13.

Stevenson, J., Lunine, J., et al. (2015). Science Advances, **1**, e1400067

Teanby, N. A., Irwin, P. G. J., et al. (2012). Nature **491**(7426): 732-735.

Tobie, G., Mocquet, A., et al. (2005). Icarus **177**(2): 534-549.

Zhou, L., Zheng, W. J., et al. (2010). Astrophysical Journal **718**(2): 1243-1251.